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Hydration of the lithospheric mantle by the descending plate in a continent-continent collisional setting

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When continents collide, can the orogenic crust be thickened by the process of wholesale underthrusting of the descending plate (Zhou & Murphy, 2005)? Actually, thick lithospheric plates collide after complete subduction of the oceanic plate in between. Thus, the role of the lithospheric mantle below the upper plate must be considered to answer this question. As the descending plate, especially its former near-surface region, significantly dehydrates, the hydration of this mantle portion was studied. For this reason, pressure (P) - temperature (T) and T- H_2O pseudosections were calculated for an average mantle composition using the computer software PERPLE_X (Connolly, 2005). These pseudosections were contoured by isopleths for volumes of amphibole, chlorite, and serpentine. It can be easily recognized from the produced graphs that considerable amounts of amphibole and chlorite can result from addition of some water to the dry ultrabasite. In the P-range 8 to 15 kbar, a maximum of nearly 20 vol.% amphibole and 10 vol.% chlorite forms when only 1.5 wt.% H_2O is added at temperatures up to 700°C. This amount of chlorite continuously disappears with rising temperatures up to 800°C and somewhat more. In the given P-range, serpentine forms only below 600°C and H_2O contents >2 wt.% added. For example, at 550°C and 5 wt.% H_2O hydrous phases amount to about 35 vol.% serpentine, 10 vol.% of each chlorite and amphibole and very little biotite in the studied ultrabasite.

As the hydration of the lithospheric mantle below the upper plate would change its rheological properties, the following geodynamic scenario is conceivable: The tip of the descending continental plate hydrates this mantle portion and weakens it. This allows the buoyant tip of this plate to penetrate the lithospheric mantle close to the interface of mantle and overlying crust. As the dehydration of the penetrating continental crust continues by heating, the hydration and weakening of the mantle is also ongoing to cause a significant penetration and, thus, a wholesale thrusting of the descending plate under the other continental plate, eventually with a thin hydrated mantle region in between. For example, pelitic rocks, common in the upper portion of continental crust, can release about 2.5 wt.% H_2O between 450 to 650°C at 10-15 kbar (e.g. Massonne et al., 2013). A pile of 3 km of such rocks extending over 300 km perpendicular to the initial orogenic front could supply so much water to produce a 500 m thick weak zone in the mantle with about 20 vol.% amphibole and 10 vol.% chlorite over 3000 km. The termination of the underthrust process can be caused by heating of the frontal portion of the underthrust plate to 650°C and more, which is then not anymore capable to hydrate the lithospheric mantle.

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